

**Results of Phase I Groundwater Quality  
Assessment for Single-Shell Tank Waste  
Management Area S-SX at the  
Hanford Site**

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## Summary

Pacific Northwest National Laboratory (PNNL) conducted a Phase I, Resource Conservation and Recovery Act of 1976 (RCRA) groundwater quality assessment for the Richland Field Office of the U.S. Department of Energy (DOE-RL), in accordance with the Federal Facility Compliance Agreement. The purpose of the investigation was to determine if the Single-Shell Tank Waste Management Area (WMA) S-SX has impacted groundwater quality.

The WMA is located in the southern portion of the 200 West Area of the Hanford Site and consists of the 241-S and 241-SX tank farms and ancillary waste systems. The unit is regulated under RCRA interim-status regulations (40 CFR 265, Subpart F) and was placed in assessment groundwater monitoring (40 CFR 265.93 [d]) in August 1996 because of elevated specific conductance and technetium-99, a non-RCRA co-contaminant, in downgradient monitoring wells. Phase I assessment, allowed under 40 CFR 265, provides the owner-operator of a facility with the opportunity to demonstrate that the regulated unit is not the source of groundwater contamination.

Major findings of the assessment are summarized below:

- Distribution patterns for radionuclides and RCRA/dangerous waste constituents indicate WMA S-SX has contributed to groundwater contamination observed in downgradient monitoring wells. Multiple source locations in the WMA are needed to explain spatial and temporal groundwater contamination patterns.
- Drinking water standards for nitrate and technetium-99 are currently exceeded in one RCRA-compliant well (299-W22-46) located at the southeastern corner of the SX tank farm. Technetium-99, the constituent with the highest concentration relative to a standard, is currently four to five times the U.S. Environmental Protection Agency (EPA) interim drinking water standard of 900 pCi/L. Technetium-99 also recently increased to just above the drinking water standard in an older well (299-W23-1) inside the S tank farm.
- Technetium-99, nitrate, and chromium concentrations in downgradient well 299-W22-46 (the well with the highest current concentrations) appear to be declining after reaching maximum concentrations in May 1997. Observations during the next four quarters are needed to confirm the apparent declining trend in this well.
- Cesium-137 and strontium-90, major constituents of concern in single-shell tank waste, were not detected in any of the RCRA-compliant wells in the WMA network, including the well with the highest current technetium-99 concentrations (299-W22-46). This observation is consistent with the low expected mobilities of these constituents under Hanford Site conditions.
- Low but detectable strontium-90 and cesium-137 were found in one old well (2-W23-7), located inside and between the S and SX tank farms. Additional investigation is needed to determine if the low level contamination is borehole related or is more broadly distributed in the aquifer.

- Preliminary results for groundwater samples collected on 1/13/98 from a new borehole (41-09-39), drilled through the primary contaminant zone down to groundwater in the SX tank farm, suggest little if any tank waste reached the water table at this location. Gross alpha and gross beta concentrations,  $2.3 \pm 0.7$  and  $16.6 \pm 4.0$  pCi/L (based on 10 sample results), respectively, are within the range of Hanford Site natural groundwater background and hexavalent chromium, an important indicator of mobile constituents in tank waste, was not detected ( $<10$  µg/L).
- Infiltration of snow melt runoff and/or artificial sources of water near vadose zone contamination sites within the WMA are possible causes of the short-term transients in contaminant concentrations observed in WMA groundwater monitoring wells between 1986 and the present. Continuing efforts are underway to identify and eliminate potential water sources around tank farms.
- A Phase II investigation of the nature, extent and source(s) of recurrent groundwater contamination at this WMA is indicated.

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# 1.0 Introduction

This report presents the findings and conclusions of a Phase I, *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater quality assessment of Single-Shell Tank Waste Management Area (WMA) S-SX as required by 40 CFR 265.93 9(d). Pacific Northwest National Laboratory<sup>(a)</sup> conducted the assessment from August 1996 to July 1997. The WMA S-SX is located in the southern portion of the 200 West Area of the Hanford Site (Figure 1.1). The area encompasses the 241-S and 241-SX tank farms consisting of:

- 27 single-shell tanks (fifteen 1,000,000-gal capacity tanks in the SX farm and twelve 750,000-gal tanks in the S farm) that contain highly radioactive nuclear fuel reprocessing and chemical wastes
- ancillary waste systems (e.g., tank farm transfer lines, diversion boxes, valve pits, and saltwell pumping pipeline network).

## 1.1 Background

Although decommissioned in 1980, the single-shell tanks are considered to be “actively” storing hazardous and radioactive wastes and have been designated as RCRA facilities, which require groundwater monitoring in accordance with interim-status regulations. The tanks in WMA S-SX are RCRA treatment and storage units and will be closed in accordance with Washington Administrative Code (WAC) 173-303-610.

A detection-level groundwater monitoring program for WMA S-SX was initiated in 1990. This regulated unit was placed in assessment-level monitoring status in May 1996 in response to a directive from the State of Washington Department of Ecology (see Appendix A, Caggiano 1996). The directive cited anomalous trends in technetium-99 and elevated specific conductance in vicinity groundwater as primary reasons for the assessment. A groundwater quality assessment plan was written in response to the Ecology directive (Caggiano 1996) and was submitted in August 1996.

The first determination (referred to herein as Phase I), and the subject of this report, is a short-term sampling program intended to provide the owner/operator an opportunity to substantiate a false positive claim. If the owner/operator determines, based on the results of Phase I determination, that no dangerous waste or dangerous waste constituents from the facility have entered the groundwater, then he may reinstate the detection-level monitoring program. If, however, contamination is confirmed (i.e., the regulated unit is the source of groundwater contamination), then a second part of the groundwater quality assessment plan (referred to herein as Phase II) should be written and implemented to fully characterize sources, driving forces, and to define the rate and the extent of migration of contaminants in the groundwater, and

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concentration of contaminants. In addition, information gained during Phase II investigations could be used to decide whether corrective measures are warranted.

**Figure 1.1.** Location Map of Single-Shell Tank WMA S-SX and Surrounding Facilities in 200 West Area  
(inset shows individual tank farms and tank numbers in WMA S-SX)

## 1.2 Objectives and Scope

The primary objectives of this assessment were to determine if observed changes in groundwater quality are due to WMA S-SX, and if so, identify sources, driving forces, and pathways to groundwater. Figure 1.2 shows monitoring well locations for the Phase I assessment.

The scope of this report is limited to description of new information acquired in connection with the assessment. Background information concerning hydrogeology of the area, monitoring network and descriptions, physical and chemical description of sources, and related background information are included in the assessment plan (Caggiano 1996) and are incorporated in this report primarily by reference.

Parallel to this investigation, an expert panel (the “Panel;” DOE 1997), was convened to independently assess the likelihood that tank waste liquor and associated contaminants, especially cesium-137, had migrated to greater depths in the vadose zone than expected. The Panel’s findings and recommendations are incorporated and referenced as appropriate.

## 1.3 Report Contents

Section 2.0 of this report describes the conceptual model used for the Phase I assessment, including a summary of source characteristics, pathways, and driving forces. Results of the data evaluation are described in Section 3.0 and include discussion of stratigraphy, driving forces, isotopic and chemical ratios, groundwater flow directions, moisture content, and co-contaminants. Section 4.0 discusses postulated contaminant source, pathway, and driving force scenarios. Source, pathway, and driving forces also are correlated with monitoring data in Section 4.0. Conclusions and a proposed approach for further investigation are provided in Sections 5.0 and 6.0.

Stratigraphic correlations and analytical results for groundwater samples collected during 1996 and 1997 are presented and discussed in Appendix A and Appendix B, respectively. Appendix C provides a discussion of chemical fractionation in single-shell tanks in the SX tank farm. A summary of tank compositions is beyond the scope of this report but are available in Agnew (1997) and from the Hanford TWRS web page.

**Figure 1.2.** Location Map of Groundwater Monitoring Wells Around WMA S-SX (the WMA, shown as

the outlined area surrounding the S and SX tank farm, consists of the single-shell tanks and associated transfer lines, diversion boxes, and other related waste-handling equipment)

## 2.0 Conceptual Model

The conceptual model is part of the Data Quality Objectives (DQO) process that was used in developing a sampling and analysis plan for the Phase I assessment (Caggiano 1996). Also, in accordance with the DQO process, conceptual models are updated as an investigation evolves.

This section describes the soil pathway conceptual model of hypothetical sources, constituents of interest, driving forces, and pathways to groundwater considered during the Phase I investigation. Figure 2.1 shows the model as presented in the assessment plan (Caggiano 1996). The primary features of the conceptualization are discussed in the following subsections, along with additional considerations from the Panel (DOE 1997) and from the Tank Waste Remediation System (TWRS) vadose zone characterization program (DOE 1996, 1998).

### 2.1 Nature of the Source

The source term for WMA S-SX is dependent on both nuclear and chemical aspects of the process that generated the waste. The manner in which the waste entered the soil column, as illustrated in Figure 2.1, and discussed in the following subsections, is also important in understanding potential sources within the WMA and the likelihood of mobile tank waste constituents reaching groundwater.

#### 2.1.1 Chemical Processing and Tank Conditions

contained fission products and lesser amounts of neutron activation products as well as the unspent uranium and transuranic radionuclides. The plutonium was chemically extracted from the fuel matrix at T plant and S plant in the 200 West Area, and B plant and A plant in the 200 East Area.

The S and SX tank farms contain aqueous waste generated from the REDOX process that was conducted in S plant from 1952 to 1966 (Agnew 1997). The chemical processing steps and waste routing are illustrated schematically in Figure 2.2. The aluminum cladding was first removed from the fuel with caustic in the dissolver vessel. Waste from this step is referred to as coating wastes or CWR waste. Some fission product activity and uranium were associated with this waste type, but less than generated during the subsequent dissolution of the declad fuel with concentrated nitric acid. After the initial dissolution of the fuel, ozone, permanganate and dichromate were used to adjust the oxidation state of the plutonium to facilitate its separation in solvent extraction columns. Aluminum nitrate was also added to enhance the transfer of plutonium ("salting out") from the aqueous to the organic phase. The highly acidic waste stream was then over neutralized with sodium hydroxide and routed to tanks in the S and SX tank farms. This process generated a much smaller volume of waste than was generated by the older bismuth phosphate process used at T plant. Thus fission product concentrations were higher in the S plant waste. The high pH also resulted in formation of precipitates of uranium, heavy metals, and strontium-90 that eventually settled to the bottom of the tanks.

**Figure 2.1.** Soil Pathway Conceptual Model. Purple depicts tank waste and leakage during early operations in the 1960s. Subsequent hypothetical movement of contaminants through the vadose zone, shown in red, yellow, and green, covers a time period from early operations to the present. As a result of volume reduction measures, a much smaller volume of free liquid remains in the tanks today.

Depth to groundwater is 210 ft (64 m). The tank base elevation is about 50 ft (15 m) below ground surface. The geologic strata shown are simplified for illustration purposes. Detailed stratigraphic descriptions are provided in Appendix A.



**Figure 2.2.** REDOX Process and Waste Stream Flow Sheet with Expected Mobile Waste Constituents. Molar proportions of nitrate, aluminum and chromium based on inventory estimates for tanks SX-109 and SX-115 are: N:Al:Cr = 1/0.5/0.1 and corresponding mass of solids is 1.45E+6 kg and 6.75E+4 kg, respectively (from Agnew 1997).

Classification of the REDOX waste stored in the S and SX tank farms as a RCRA/dangerous waste (or hazardous waste) is primarily because of the hexavalent chromium, the corrosive (high pH) nature of the waste, aluminum and nitrate. The principal radioactive components of concern, although not explicitly regulated under RCRA, are cesium-137 and strontium-90, initially present in the 0.1 to 1 Ci/L range. Long-lived mobile constituents, technetium-99 and iodine-129, were on the order of 10's of  $\mu\text{Ci/L}$  or less. A large fraction of the latter two fission products, especially iodine-129 may have been separated as a gaseous phase during fuel dissolution. In addition, the low burn up of the fuel (short irradiation times) results in relatively low inventories of iodine-129 as compared to high burn up commercial reactor fuel. Transuranic radionuclides (e.g., neptunium-237, plutonium-238, -239, americium-241) are also present as either a byproduct of the separation step or due to incomplete removal during the solvent extraction step. The chemical state of the transuranics is uncertain due to the elevated pH of the stored waste. Much of the transuranic inventory should be associated with solids in the tanks. There may be a tendency, however, for the formation of soluble oxyanions at elevated pH. Neptunium-237 is expected to have the greatest tendency to form soluble anionic chemical species.

because of tank waste chemical conditions, the transuranics, as well as strontium-90, are expected to be predominantly particulate or associated with a solid phase or chemical precipitates. Complexants (e.g., EDTA), that may still be present in some tanks, however, could alter this generalization. Single-shell tank sludge/core samples and fractionation results should provide more definitive information about chemical states of tank waste constituents. (Results for tanks are posted on the Hanford/TWRS web page as they become available). Chemical fractionation is discussed in more detail in Appendix C.

steel surrounded by a layer of reinforced concrete which forms the roof and sidewall support. The tanks shown as leakers in the SX farm (Figure 1.2) were unique. The bottom edge of the walls of these tanks were welded directly to the floor of the tanks. Other tanks in the S and SX farms were constructed with a curved bottom edge. The welds in the former case apparently failed due to accelerated corrosion and or physical stress induced by buckling beneath the center regions of the tank bottoms. The buckling caused the floor to pull away from the wall at the welded seam. The buckling was attributed to decay heat that generated intense pressures between the concrete base and the carbon steel floor. This condition may have also contributed to expulsion of superheated steam and liquid waste into the surrounding soil (DOE 1997).

Chemical processing waste from S plant was routed to diversion boxes and then to the subject tanks were operated in a self boiling mode to reduce tank waste volumes. This involved condensing the water vapor, driven off as tritiated steam, from exit ports at the top of the tanks. The condensate was discharged to upgradient cribs; no high salt tank waste supernate was discharged to adjacent disposal facilities.

individual tanks in S and SX tank farms. Waste was also transferred from tank to tank. The waste entered the tank farms from the east side where the diversion boxes were located, as indicated in Figure 2.1. The transfer lines were not double contained so failures would have resulted in losses to the soil.

Based on tank construction and operating conditions, as discussed above, the tanks in the SX tank farm, especially the tanks designated as leakers (Figure 1.2), are the largest sources of potential groundwater contamination in WMA S-SX. Previous studies (WHC 1992a,b,c) and recent vadose zone characterization data (DOE 1996, 1998) indicate that tanks SX-108, 109 (west central) and tank SX-115

(southwest corner) of the SX tank farm are the largest sources of subsurface contamination. Large volume losses from transfer lines and related spills, however, cannot be ruled out as potentially significant contributors to vadose zone contamination in WMA S-SX and vicinity.

### 2.1.2 Release Modes and Soil Chemical Conditions

As indicated in Figure 2.1, and discussed above, potential tank sources that hypothetically could contribute to groundwater contamination include: 1) leaks from the base of the tanks, and 2) transfer line/ diversion box leaks. As the Panel noted in their report, the multi-molar (sodium nitrate) waste liquor was hot (175°C), dense (up to 2 g/cc), and highly caustic (pH up to 14). This combination could have dissolved silica and aluminates from the soil matrix, increased the soil porosity and enhanced downward migration. However, it also is possible that the dissolved silica and aluminum from the aluminosilicate minerals could have precipitated as the mass cooled at a somewhat greater depth. If this occurred, the main mass of the initial leak, whether from a tank or other source(s), should remain relatively high in the soil column. Laboratory studies on simulated tank waste confirm the formation of aluminum hydroxide gels in high pH media in contact with basaltic material and Hanford soils, and the plugging action it has on laboratory leaching columns (Serne, Zachara, and Burke 1997). If the gel plugging scenario occurred in the WMA S-SX, the primary mass may still be in the vicinity of the initial emplacement volume of contaminated soil (i.e., the approximate location indicated by the initial leak in Figure 2.1). If plugging did not occur, then the entire mass of tank leakage should have moved downward in a broad

If plugging of the soil column (by precipitation subsequent to the reaction of the caustic waste liquor with the soil) did not occur, then the entire mass of tank leakage should have moved downward in a broad “wetting front,” with the more mobile constituents (e.g., chromate, nitrate, and technetium-99) at the leading edge, as Figure 2.1 depicts. The same type of fractionation with depth could occur from more broadly distributed, but lower level contamination, as suggested by recent vadose zone characterization efforts in the S and SX tank farms (DOE 1998). The shape of the wetted zone with depth could vary considerably from that depicted as a result of stratigraphic fine structure and or preferential pathways (DOE 1997). Unplanned releases such as surface spills as a result of “bumping” during boiling in the SX

tanks resulted in dispersal of tank waste to the surrounding ground surface. These sources were “watered in” and covered with gravel. Evidence of significant surface contamination exists over much of the tank farm, including the area outside the south fenceline of the SX farm. The contaminated area at this location occurs on a bank that slopes downward into a large barrow pit where snow melt and runoff also accumulates. Artificial sources of water have existed in this area as well (water lines and a sanitary drain field). Near-surface contamination can be transported deeper into the vadose zone more readily at such locations.

Overflows of waste (enroute to single-shell tanks) at diversion boxes and “jumpers” and at the inlet and outlets of the tanks also contributed to near-surface soil contamination in the WMA. These “spill” sources could be sources of groundwater contamination that would be indistinguishable from tank leak sources.

## 2.2 Pathways

The non-homogeneous nature of the sedimentary units beneath the WMA play an important role in contaminant movement. The fine sediments within the coarser material tend to spread the liquid waste over a larger area and impede downward movement, as suggested in Figure 2.1. Potential preferential vertical pathways depicted in Figure 2.1, should they exist, would accelerate movement through the sedimentary layers by providing “short circuits” for moisture movement. The prevalence of natural vertical features (e.g., clastic dikes) or macro porosity in the 200 West Area may suggest such features could exist beneath the S and SX tank farms.

Artificial pathways include the unsealed boreholes installed around each tank to depths of 75 to 130 ft (23 to 40 m) for leak detection purposes. In addition, five wells were drilled to groundwater in the S and SX farms, three of which are adjacent to tanks. Thus, manmade conduits are possible short circuits to groundwater as well.

In addition to the above pathways, the Panel (DOE 1997) pointed out that irregular moisture movement can occur even in homogenous sands that lead to flow channels through the vadose zone. These features can “siphon” the soil water and lead to more rapid transport to groundwater. Once such pathways are formed or “wetted”, subsequent transport events occur more readily. Such features are difficult to depict graphically, and thus are not shown in Figure 2.1. The general concept, however, is acknowledged as a variant on preferential pathways that could shorten the travel time to groundwater.

## 2.3 Driving Forces

Contaminant transport through the soil column requires either an external source of water to carry the contaminants to groundwater or a leak of sufficient volume to make it to groundwater. The density of the fluid can enhance this downward movement as well.

Sources of water include both natural precipitation and artificial sources. Infiltration of natural precipitation is enhanced due to the coarse gravel cover over the tank farms. This effect is amplified around the base of the tanks as a result of runoff from the tank dome, as Figure 2.1 shows. Artificial sources include potable water line ruptures or leakage, adjacent crib sources, fire hydrant supply line leakage, and discharge testing water. Surface water runoff from roads and parking lots that accumulates in low spots near subsurface contamination associated with the WMA is another potential driving force/source combination.

## 2.4 Constituents of Interest

Mobile WMA-related waste constituents in groundwater, that can be distinguished from adjacent sources, could be indicative of a tank leak, spill, or related WMA source. The principal mobile tank waste co-contaminants identified for WMA S-SX are technetium-99 (as  $\text{TcO}_4^-$ ), hexavalent chromium ( $\text{CrO}_4^{2-}$ ) and nitrate ( $\text{NO}_3^-$ ). The latter two constituents are RCRA hazardous waste constituents (or *listed wastes*). Tritium also is present in the tank waste, but there have been much larger sources of upgradient tritium because of past-practice discharges (e.g., cribs) of tritium-bearing tank condensate. Thus, tritium from sources within the WMA would be masked by upgradient tritium sources. Nevertheless, tritium is useful

as an indicator of flow direction or perturbations in the expected flow direction between the upgradient source(s) and downgradient S-SX monitoring wells. In combination with other WMA waste indicators, it may help delineate source areas or constrain possible source locations.

Other non-radioactive co-contaminants include the major cation ( $\text{Na}^+$ ) associated with the high salt matrix (i.e., sodium nitrate). However, the sodium could exchange for or displace other exchangeable cations in the soil column ( $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ) and alter the major cation composition reaching groundwater. In this case, calcium and magnesium in combination with nitrate should account for the elevated total dissolved solids or specific conductance expected from a leak that reaches groundwater. Variations resulting from release conditions, leak volume, and pathway could occur. For example, if the waste liquor volume associated with a leak or discharge is very large ( $\gg$  pore volume of the soil column beneath a leak area), all the naturally occurring exchangeable cations in the soil column in contact with the waste liquor should be replaced by sodium. After the initial “pulse” of displaced calcium and magnesium passes, the receiving groundwater would be dominated by sodium. If the leak is smaller than a pore volume, the “imprint” in groundwater near the source would be calcium and magnesium-dominated because the displaced cations from the soil column would not be flushed away, as would occur with multiple pore volumes of high sodium waste liquor. However, if a short circuit pathway such as an unsealed monitoring well transports the waste liquor directly to groundwater, then the dominant cation could be sodium even if the leak volume is relatively small.

Strontium-90 and cesium-137, the major radioactive tank waste constituents of concern, are not expected to be mobile under normal Hanford Site conditions. Because of findings from the TWRS vadose characterization program, suggesting cesium-137 may have migrated to greater depths than previously thought, these moderately long-lived fission products were included in the analyte list for the assessment.

In addition to the use of isotopic ratios (e.g.,  $^{99}\text{Tc}/\text{U}$ ,  $^3\text{H}/^{99}\text{Tc}$ ), the relative proportions of the major cations in groundwater (e.g., Na/Ca ratio) could also be used to “fingerprint” contaminant sources. These ratios provide additional clues concerning the nature and/or location of potential sources of groundwater contamination in the vicinity of tank farm WMAs when combined with other information.

Transuranic radionuclides, although potential constituents of interest, were not analyzed for this assessment. Gross alpha concentrations, however, were measured as an indicator. When anomalous gross alpha is observed, isotope specific analyses are requested. As discussed in Appendix B, gross alpha data did not suggest the presence of above-background alpha activity in wells where maximum technetium-99 was observed. A special request, however, was made for analysis of plutonium-239, americium-241 and neptunium-237 in samples from the new borehole drilled in the SX farm.

## 3.0 Results

This section summarizes additional groundwater and related data acquired during the Phase I assessment (August 1996 to August 1997). A data tabulation and discussion of sampling conditions and analytical results are included in Appendix B. Interpretation of new and previous findings and consistency of observations with the conceptual model are discussed in Section 4.0.

### 3.1 Co-Contaminant Patterns

As discussed in Section 2.0, the primary mobile co-contaminants associated with a tank or related source should co-vary in groundwater at a specific well or wells if a WMA source is responsible for the observed change in groundwater quality. Accordingly, the quarterly results for technetium-99, chromate, and nitrate for the upgradient and downgradient RCRA-compliant network monitoring the SX tank farm are shown in Figure 3.1. As can be seen from Figure 3.1, all three constituents are co-variant and show increasing trends over time in both wells 2-W23-15 and 2-W22-46 (see Figure 1.2 for location). The abrupt increases in all three co-contaminants that began to emerge for well 2-W22-46 in 1997 mimic patterns observed in well 2-W23-15 that occurred during the 1992-1993 period.

Supplemental sampling in two older wells located between 2-W23-15 and 2-W22-46 was conducted to determine if there were any spatial relationships. Wells 2-W23-3 and 2-W23-6, which were not previously equipped with sample pumps, were first inspected and pumps installed before sampling. Initial results show that well 2-W23-3, located immediately downgradient from the primary single-shell tank leak sources (SX-108 and 109) in the SX tank farm, exhibited very low technetium-99 concentrations (60 pCi/L). This is consistent with previous measurements for this well based on bailed (non-purged) sampling results. In sharp contrast, technetium-99 in nearby well 2-W23-6 sampled in July 1997 was 2,100 pCi/L (no previous results were available in the data base for this well). The significance of these observations is discussed later (Section 4.0).

It should also be noted that technetium-99 increased from 180 pCi/L in 1996 to 1,500 pCi/L (on 8/7/97) in well 2-W23-1, located inside the S tank farm. This is the only well in the vicinity of WMA S-SX that is currently indicating an upward trend.

### 3.2 Sodium/Calcium Relationships

As discussed in the assessment plan, excess calcium and magnesium showed a co-variance with the major mobile anionic co-contaminants (nitrate, chromate, and technetium-99) in well 2-W23-15 (Figure 3.2). The excess calcium and magnesium (excess = observed minus upgradient concentrations) in meq/L are also very close to the major anion (nitrate) indicating the major contributors to the total dissolved solids and/or specific conductance during the peak period were due to these constituents ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{NO}_3^-$ ). An unaltered tank waste source would be dominated by  $\text{NaNO}_3$ . However, as indicated in Section 2.0, the dominance of

**Figure 3.1.** Time Series Plots of Technetium-99, Chromium, and Nitrate in the WMA S-SX Monitoring

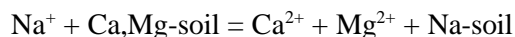
Well Network (concentrations of chromate are in micrograms per liter of chromium, as reported by the vendor;  $\mu\text{g/L of CrO}_4 = 2.28 \times \text{Cr}$ )

**Figure 3.2.** Mobile Co-Contaminant Concentrations Versus Time in Well 299-W23-15. (a) Chromate

in parts per billion or micrograms per liter of  $\text{CrO}_4^{=}$  and nitrate in parts per million or milligrams per liter of  $\text{NO}_3^-$  (b) concentrations of excess calcium + magnesium and nitrate are expressed as meq/L, obtained by dividing the constituent concentration in mg/L by its gram-atomic weight and multiplying by its ionic charge.



calcium and magnesium, rather than sodium, in groundwater beneath a hypothetical tank farm source could occur as a result of the following cation exchange reaction:



Current trends noted in well 2-W22-46 have not developed well enough to confirm patterns recognized earlier for well 2-W23-15, but the same constituents appear to be following the trend illustrated in Figure 3.2.

It should be noted that the anion and cation relationship discussed above is not unique to a tank waste source; i.e., the anionic charge must be balanced by some cation or mix of cations regardless of the original nitrate source. Nitric acid, for example, could react with soil carbonates and result in a calcium nitrate waste that reaches groundwater. The important point to be made above, and in Figure 3.2, is that the dominance of calcium and magnesium, rather than sodium, in the downgradient monitoring wells does not rule out a sodium-dominated tank waste or related waste liquor source.

### 3.3 Tritium Pattern

In contrast to the co-variance noted above, tritium (Figure 3.3) in well 2-W23-15 follows a distinctly different pattern, suggesting a different origin for this waste constituent. Also, tritium currently is much higher in the upgradient well (2-W23-14) than in the downgradient wells. The most likely source is drainage of residual tritium from the major S-SX tank farm condensate disposal site (e.g., from 216-S-21 Crib) that received nearly 100 million liters of tank condensate containing tritium at concentrations of 10-100  $\mu\text{Ci/L}$  (see Figure 1.2) for crib location.

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**Figure 3.3.** Tritium Concentrations Versus Time in WMA S-SX RCRA Monitoring Well Network

### 3.4 Isotopic and Chemical Ratios

The relationship of tritium and technetium observed in upgradient wells (very high tritium and very low technetium-99), reflect the separation of tritium as tritiated water vapor from the high salt, self-boiling tank waste from the S and SX tank farms. The technetium-99 and other non-volatile chemical constituents became more concentrated as the boiling progressed, and the resulting tritiated water vapor phase was condensed and discharged to adjacent cribs.

Upgradient crib sources may be distinguishable from tank sources because of the fractionation of the original tank waste liquor caused by the self-boiling operation. This process was unique to the S-SX tanks (in the 200 West Area) as a means of volume reduction to save tank space. The high salt tank waste supernatant was discharged to adjacent upgradient cribs at the S and SX tank farms. This high salt tank waste is not found elsewhere (e.g., T, TX, TY and B, BY, and BX).

The different source areas for the tritium and technetium-99 are clearly evident in the tritium and technetium-99 concentration contour plots shown in Figure 3.4. Technetium-99 appears to originate in the S and SX tank farm area while the tritium seems to originate to the west of the WMA near the upgradient crib sources noted above. It should also be noted that other major downgradient sources exist, especially for technetium-99. For example, the technetium-99 contours near the upper right corner of Figure 3.4 originated from past-practice disposal sites associated with U Plant operations.

The ratio of tritium to technetium-99 versus technetium-99 concentration for the wells in the immediate vicinity of the WMA are shown in Figure 3.5 (only wells within about 500 m of the WMA are included in order to avoid confusion with downgradient sources). The expected tritium/technetium-99 ratio from single-shell tanks in the S or SX tank farms is in the range of 1-10, based on data and considerations provided in Agnew (1997). The overall distribution of ratios in Figure 3.5 appears to be a mixture of an upgradient source with a very high ratio and a WMA-related low ratio source.

If upgradient groundwater sources were responsible for the elevated technetium-99 concentrations observed in groundwater beneath WMA S-SX, the tritium/technetium-99 ratio should be somewhat uniform both upgradient and downgradient of the WMA. The dramatically lower tritium/technetium-99 ratio in downgradient wells is attributed to an increase in the technetium-99 from a localized input source that lowers the ratio. Low concentrations of technetium-99 observed in the upgradient wells indicate that the WMA is (or was) the source of the added technetium-99.

In addition, technetium-99/uranium ratios (Figure 3.6) were used to distinguish separate source types. The average ratio for inputs to adjacent crib sources (very low ratios, Figure 3.6), and apparent high ratios for a tank waste source (>300 based on the water soluble fraction of tank waste sludge, Caggiano 1996), are more consistent with a source originating within the WMA (e.g., single-shell tanks and or ancillary waste systems) than an adjacent crib.

In addition to the indications based on isotopic ratios, the technetium-99 groundwater plume also suggests an origin somewhere within or at least in the vicinity of WMA S-SX (see Figure 3.4).

**Figure 3.4.** Concentration Contours for Tritium and Technetium-99 (1996)

Figure 3.5.

Tritium/Techneium Ratio versus Technetium Concentration in Selected Wells (data shown

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the 1996 average values for 12 wells in the immediate vicinity of WMA S-SX. See Figure

for specific well locations. The two straight lines are a best visual linear fit to the data

The data suggest there are two separate mixing regimes. One that starts with the northern upgradient RCRA well, 2-W23-13, and extends to downgradient wells in a southeasterly direction. This inferred mixing line begins with an upgradient source that has a technetium concentration of about 1 pCi/L and a tritium concentration of about 200 pCi/L. The other inferred mixing line begins with the south upgradient RCRA well, 2-W23-14, and a ratio of about 10,000 and appears to be associated with a mixing line consisting of data from wells at the south end of the WMA. The spatial relationship of the wells indicated along the inferred mixing lines above are consistent with inferred flow directions discussed in Section 3.6. If

technetium in downgradient wells originated from an upgradient source containing both

and technetium, the ratios should not vary significantly along an inferred flow path even

concentrations may vary. As illustrated by the solid mixing line above, the ratios decline by three orders of magnitude as technetium concentrations increase by nearly three orders of magnitude. Also, both mixing lines seem to converge at a ratio in the range of 1 - 10, a range consistent with a WMA S-SX tank waste or related source).

**Figure 3.6.** Technetium/Uranium Ratio in Groundwater Near WMA S-SX

### 3.5 Depth Variations

The occurrence of technetium-99 in well 2-W22-46 during 1997 offered an opportunity to examine variations with depth. A Hydrostar pump was set at about 1 ft (0.3 m) below the static water level in order to determine if concentrations were higher near the top of the aquifer as compared to the normal sample depth at 5-7 ft (1.5-2.1 m) below the static water level in the well. Table 3.1 shows a comparison of constituents of interest at two different sample pump depths.

#### 3.5.1 Depth Relationships

There is very little difference in concentrations of constituents sampled from the very top of the aquifer as compared to the normal depth. However, because of the declining water table, due to termination of local discharges to the ground in 1995, the available monitoring wells at S-SX have less than 10 ft (3 m) of water remaining in them. New wells would be needed, or existing wells extended, to more fully evaluate distribution with depth in the upper aquifer and to replace wells that go dry.

#### 3.5.2 Compositional Relationships

It is also noteworthy that cesium-137 and strontium-90 were undetected in the same samples (unfiltered) in which the mobile tank waste constituents are relatively high (Table 3.1). This is consistent with the expected differences in mobilities ( $K_d$ s) for cesium, strontium, and technetium. The activity ratio of technetium-99 to cesium-137 or technetium-99 to strontium-90 in the soluble fraction of tank waste is on the order of 0.0001 and 0.01, respectively (Agnew 1997). That technetium-99 concentrations of up to 5,000 pCi/L were observed in well 2-W22-46 while cesium-137 and strontium-90 were undetected, suggests that if high salt waste liquor in WMA S-SX is the source of technetium-99 in well 2-W22-46, then significant fractionation of the radioactive components has occurred in the soil column and/or aquifer, as depicted in the conceptual model (see Section 2.0). If cesium were completely mobile,  $K_d = 0$ , the expected concentration in groundwater containing 5,000 pCi/L of technetium-99 would be:

$$Cs-137 = C/R = (5,000 \text{ pCi/L})/0.0001 = 5 \times 10^7 \text{ pCi/L}$$

where C is the observed technetium-99 concentration in groundwater and R is the ratio of technetium-99/cesium-137 in tank waste. Migration rates for cesium-137 and strontium-90 are expected to be significantly slower than for technetium-99 based on laboratory sorption studies (Serne et al. 1997). However, if sorption of cesium and strontium are greatly reduced, or are essentially not adsorbed due to the chemical matrix of the tank liquor, and/or there is a short circuit pathway to groundwater (Section 3.7), very high concentrations of cesium-137 and or strontium-90 should be observed in groundwater along with the technetium-99.

Whatever the pathway or initial and final sorption conditions, the above considerations indicate that the net effect is for significant retention of cesium-137 and strontium-90 in the vadose zone and/or on aquifer solids.

Also, based on the data in Table 3.1, either the “zero” cesium sorption conceptualization is incorrect, or the WMA is not the source of observed technetium-99 and other mobile tank waste contaminants in

groundwater. However, the latter seems unlikely in view of the tritium/technetium-99 ratio pattern illustrated in



Table 3.1.

Effect of Sampling Depth on Constituent Concentrations at Well 2-W22-46 (May 1997)

Constituent (Units of Measurement)	Sampled Depth	
	Shallow <sup>(a)</sup>	Normal <sup>(b)</sup>
Radionuclides <sup>(c)</sup>		
<sup>3</sup> H (pCi/L)	65,200 ± 4,940	NA
<sup>99</sup> Tc (pCi/L)	4,280 ± 473	5,020 ± 558
<sup>90</sup> Sr (pCi/L)	-0.05 ± 0.18	0.20 ± 0.22
<sup>129</sup> I (pCi/L) <sup>(d)</sup>	NA	0.47 ± 0.42
<sup>137</sup> Cs (pCi/L)	3.21 ± 2.52	-0.83 ± 4.92
U (µg/L)	NA	4.56 ± 1.01
Gross Alpha (pCi/L)	2.65 ± 1.15	2.27 ± 1.76
Chemical Constituents (filtered)		
NO <sub>3</sub> (µg/L)	46,500	52,200
CrO <sub>4</sub> (µg/L) <sup>(e)</sup>	35	39
Cl (µg/L)	3,450	3,550
SO <sub>4</sub> (µg/L)	14,900	14,400
Al (µg/L)	97.1B	20.1U
Na (µg/L)	25,900	25,600
K (µg/L)	3,400	5,060
Ca (µg/L)	26,100	25,800
Mg (µg/L)	8,520	8,380
<p>(a) Pump intake was set at 1 ft below the static water level in the well.</p> <p>(b) Pump intake was set at 5-7 ft below the static water level in the well.</p> <p>(c) Reported values are measured results ±2 sigma counting errors for unfiltered samples.</p> <p>(d) Previous measurements in other monitoring wells in the vicinity of WMA S-SX also indicate non-detectable iodine-129. This is consistent with tank waste samples from SX tank farm. For example, using a median observed tank waste <sup>99</sup>Tc/<sup>129</sup>I ratio of 10,000, the expected iodine-129 concentration in the above sample would be: (5,020 pCi/L)/(10,000) = 0.5 pCi/L. Thus even though it should be present as a mobile co-contaminant, it was not detectable.</p> <p>(e) Reported as elemental chromium.</p> <p>U = Non-detect; the value shown is the vendor method detection limit.</p> <p>B = Analyte concentration below contractual quantitation limit but above method detection limit.</p> <p>NA = Not available.</p>		

Figure 3.5 and other indicators discussed above. Alternatively, there could be an initially low or zero cesium  $K_d$  near the release point, followed by a higher  $K_d$  (Ward et al. 1997) as the salt matrix is diluted in the pore fluid by infiltration of precipitation or by groundwater after the hypothetical waste liquor enters the aquifer. Direct observation of pore fluids in soil column samples beneath a leak site are needed to help resolve this issue.

It should also be noted that gross alpha results for the samples (unfiltered) from well 2-W22-46 shown in Table 3.1 were at natural background levels (2 - 3 pCi/L) typical for the Hanford Site (see Appendix B discussion). Thus transuranic alpha emitters are not expected to be present at concentrations above the 4 mrem/yr equivalent drinking water standard (1 pCi/L).

### **3.6 Flow Direction**

Variation in inferred flow direction was evaluated using the three point problem approach on several combinations of wells in the S-SX network, including some older wells for which water level data were available. The overall mean and standard deviation over the time period of 1992 to 1997 among all well combinations used is  $116 \pm 12.6^\circ$  (to the southeast). Thus, a general flow direction from northwest to southeast is inferred (Figure 3.7). The values for the south end of SX farm are somewhat lower ( $104 \pm 5^\circ$ ), suggesting a possible localized shift to a more easterly direction in this area. More precise water level measurements and/or some real time water level measurements to allow for barometric changes could enhance the reliability of inferred flow directions. Nevertheless, the general southeasterly flow indicated is consistent with expectations based on water table contours and general direction of contaminant plumes in this area.

Previous interpretations (Connelly, Ford, and Borghese 1992) of flow direction, groundwater flow velocity, and hydraulic conductivity (Figure 3.8) are consistent with the preliminary indications noted above. For example, a very low hydraulic conductivity is shown (based on limited slug test data) in the vicinity of the south end of the SX farm. This could act as a leaky barrier to groundwater flow, resulting in diversion of groundwater to the south around the low permeability zone and then in a more easterly direction. Contaminants from overlying vadose zone sources that enter the low hydraulic conductivity portion of the aquifer would migrate very slowly ( $<25$  m/yr, based on Figure 3.8 time markers). The highly variable hydraulic conductivity for the Ringold Formation illustrated in Figure 3.8 is attributed to differential cementing. This feature of the unconfined aquifer must be kept in mind when considering localized groundwater flow direction and velocity in the 200 West Area. That is, because of the anisotropy in the aquifer, flow directions can deviate from expected or inferred water table elevations alone.

### **3.7 Stratigraphy and Vadose Zone Contaminant Distribution**

Sedimentary structures play a significant role in both the movement of contaminants through the vadose zone and in controlling the distribution of natural and artificial sources of water that can mobilize contaminants. The implications of stratigraphic conditions beneath WMA S-SX summarized in this section are based on geologic and stratigraphic interpretations presented in Appendix A.



Figure 3.7. Flow Directions Based on “Three-Point” Solutions Near WMA S-SX (values were averaged over the time period 1992-1997)

### 3.7.1 Contaminant Distribution in Relation to Stratigraphic Units

The distribution of cesium-137 is a useful indicator of subsurface distribution of tank waste and related contaminants in the tank farms. Although mobile constituents not detected by spectral gamma logging may have migrated to greater depths, the distribution pattern of cesium-137 indicates the approximate location and spreading of the initial liquid waste.

Figure 3.8.

Hydraulic Conductivity in the 200 West Area (from Connelly et al. 1993; water

table elevations in feet, shown as blue contour lines, and inferred flow directions or streamlines, in red, are based on 1991 data. WMA S-SX is located within the dashed white rectangle in the colored area at the bottom of the figure.)

The depth distribution of cesium-137 based on spectral gamma logging (DOE 1996, DOE 1997, DOE 1998) is shown in relation to stratigraphy for the S and SX tank farms (Figures 3.9 and 3.10, respectively). The cross sections suggest that most of the cesium-137 is located above a gravel and sand-silt sequence that occurs at depths of 20 to 50 ft (6.1 to 15.2 m) below the tank base elevation on the west side and at depths of 10 to 30 ft (3 to 9.1 m) below the tank base on the east side of the SX tank farm (Figure 3.10). The same gravel and sand-silt sequence appears to intersect the tank base elevation along the east side of the S tank farm (Figure 3.9).

A new borehole near SX-109 (41-09-39) was gamma logged down to 130 ft (40 m) below surface and then cored and sampled to groundwater (64 m). The spectral gamma log indicates cesium-137 at the 130 ft (40 m) level, but at concentrations 1,000 to 10,000 times lower than maximum concentrations (DOE 1997) that occur above the gravel sequence. Preliminary results (Jeff Serne, personal communication) suggest that little if any cesium-137 attributable to migration through the formation occurs below the 135 ft (41 m) depth. Mobile constituents (e.g., technetium-99) are also surprisingly low to absent in the deeper sections of the core. Initial groundwater samples at the top of the aquifer, collected as part of this impact assessment, indicate hexavalent chromium is non-detectable ( $<10 \mu\text{g/L}$ ). As indicated in section 2.0, hexavalent chromium is a mobile co-contaminant present in S-SX tank farm waste. This observation is also consistent with the gross beta results for samples collected during purging for the development of the temporary well. The mean of 10 results for samples collected 1/13/98 was  $16.6 \pm 4.0 \text{ pCi/L}$ . This is within the range of Hanford Site natural groundwater background for gross beta. Thus technetium-99 (a low energy beta emitter) or strontium-90 and cesium-137 (both beta emitters), if present, must be at very low concentrations. The corresponding mean value ( $2.3 \pm 0.7 \text{ pCi/L}$ ) for gross alpha was also within natural background range for Hanford Site groundwater. Thus the alpha emitting transuranic radionuclides of interest (neptunium-237, plutonium-239, and americium-241) must be less than 1 pCi/L (the 4 mrem/yr equivalent drinking water standard).

Initial tank waste technetium-99 concentrations and predicted pore fluid concentrations (Ward et al. 1997) at the water table beneath SX-109 exceed 10,000,000 pCi/L. Thus even allowing for dilution at the water table, much higher hexavalent chromium and estimated technetium-99 concentrations should be observed if the main mass of a leak reached and is draining to groundwater. These observations suggest that either most of the waste volume leakage from SX-109 is still in the vadose zone, or that the borehole missed the path that the waste took to groundwater. The likelihood of encountering contaminant breakthrough to groundwater was enhanced by pumping a relatively large volume of water. For example, a volume of 5,000 liters was pumped from a 3-m screened interval. Thus the estimated capture zone covered an area of 10 - 20  $\text{m}^2$  (assuming an effective porosity of 0.1 for the cemented Ringold formation in which the aquifer occurs).

### **3.7.2 Stratigraphy and Potential for Lateral Movement of Water**

As indicated in (Figure 2.1), adjacent sources of water could potentially come in contact with waste sources within the WMA by lateral migration along stratigraphic features. This possibility was evaluated by examination of stratigraphy near the major subsurface soil contamination sites (Figures 3.9, 3.10, and Appendix A). Figures 3.9 and 3.10 suggest that both the near-surface gravel layer and the deeper gravel layer that are underlain by finer textured sediments could act as conduits for lateral transport of water into the tank farm. One area where this could be especially significant is near Tank S-104 where the gravel unit

and excavated (or disturbed) area coincide with the waste zone beneath the tank. Along the west side of the SX tank

**Figure 3.9** Stratigraphic and Cesium-137 Correlations for a West - East Cross Section in the S Tank Farm (based on interpretations presented in Appendix A).



**Figure 3.10.** Stratigraphic and Cesium-137 Correlations for a West - East Cross Section in the SX Tank Farm (based on stratigraphic interpretations presented in Appendix A)

farm, (see Appendix A) fine sediment layers occur beneath gravel and sand layers but do not appear to be continuous (west to east) across the tank farm. Where they do occur, they could serve as perching layers that could facilitate horizontal movement of water.

A second area of potential enhanced infiltration is at the south end of SX farm, where one of the gravel units occurs just beneath the tank base elevation. One of the largest tank leaks in the WMA occurred in the southwest corner of the SX tank farm at tank SX-115. In the area immediately adjacent to the southwest corner is a large barrow pit that can accumulate surface runoff. In addition, an old water line passes through this area. Both the pit and the water line are located over the excavated (or disturbed) zone created when the single-shell tanks were constructed.

A similar potential surface water infiltration condition exists along the east side of the S tank farm. A bank slopes inward toward the farm and creates a depression running parallel (north to south) to the tanks. Surface runoff from snow melt and accidental sources of water can accumulate in this location. This possibility was demonstrated in September 1996 when a 14-in. water main separated nearby releasing 500,000 gallons (1,900,000 L) of water in less than an hour. The water flowed into the northeast side of S tank farm and ponded in the depression at the base of the slope. Accumulation of water (from snow melt) in depressions within the central area of S tank farm have also been observed. Lateral conduits of water beneath the tanks would enhance the likelihood of intersecting vertical features, such as clastic dikes, discussed in the following section.

### **3.7.3 Vertical Movement of Water**

The textural variations in both the backfill and the sedimentary layers beneath the disturbed zone can influence the amount and timing of natural infiltration in the tank farm. The gravel surface enhances infiltration; and runoff from the domed tank structures (for example, due to snow melt events) can direct water along the outer walls down to the tank base (illustrated in Figure 2.1).

The enhanced infiltration described above could be partially offset by a combination of stratigraphy and decay heat. For example, decay heat may cause redistribution of an unknown amount of the soil moisture in the tank farms (Ward et al. 1997). Although the magnitude of this potential effect is unknown, the moisture profile (Appendix A) for the new borehole (41-09-39) near SX-109 suggests moisture contents from the surface to groundwater near tank SX-109 are not noticeably greater than observed for adjacent RCRA monitoring wells.

Preferential vertical pathways through the vadose zone have been suggested (DOE 1997) as potential short circuits to groundwater. Clastic dikes are common in the vicinity of the WMA. These vertical structures occur as polygons with cell dimensions somewhat larger than the diameter of a single-shell tank. Clastic dikes are typically near-vertical tabular fissures filled with multiple layers of unconsolidated sediments. The grain size of the layers vary from fine to coarse and are typically separated by clay-silt linings. Although clastic dikes typically are not continuous from the surface to the water table, they are common in all pre-Holocene sediments. Clastic dikes could act in combination with horizontal layers to provide a “stair-step” pathway to the water table as depicted in (Figure 2.1).

Because clastic dikes are vertical, the probability of encountering them with a vertical borehole is small. However, based on the known occurrences in the 200 West area and vicinity, the likelihood of their presence near vadose zone contamination sources in the S and SX tank farms is relatively high.

Faults, fractures and joints are structural discontinuities that can also provide potential vertical pathways to groundwater. These features are most common in competent rock near the anticlinal ridges but are not confined to only these areas. Faults have been observed throughout the Pasco Basin but are typically sparse away from the major anticlines. Joints and fractures differ from faults in that there is no offset of layers but they are very common wherever competent, brittle deforming rock has undergone folding as in the Pasco Basin. The cemented rock of the Ringold Formation (lower gravel unit near water table in Figs. 3.9 and 3.10) and caliche layers of the Plio-Pleistocene unit are typically broken by fractures and joints. The uncemented Hanford formation and ductile clay-rich beds of the Plio-Pleistocene unit are probably less susceptible to joints and fractures. However, shrinkage of clay-rich beds as they dry out will produce abundant joints and fractures.

Faults, fractures and joints are difficult to detect by most drilling methods. Significant offset of layers by faults has not been found at or near the WMA. However, joints and fractures are nearly impossible to detect even when cored because drilling usually induces joints. It is highly probable that caliche zones and the cemented Ringold Formation are cut joints and fractures and are not impermeable zones.

### 3.8 Contaminant Breakthrough

As noted above, circumstantial evidence exists for vertical pathways that could allow tank waste contaminants to follow short circuit pathways to groundwater. The depth distribution pattern of cesium-137 shown in Figure 3.10 also suggests some type of vertical feature, possibly a preferential pathway, in the vicinity of the new borehole (41-09-39). Reduced sorption could occur because of chemical matrix or *competing ion* effects. Or because of coarse grained (low surface area) dike or fracture in-fillings that are less sorptive. Particle-bound contaminants (or colloids) could reach groundwater more readily via coarse grained vertical pathways as well. Surface water could provide the driving force for downward movement or a large volume leak itself may be adequate to overcome interstitial forces.

Some initial modeling results (Ward et al. 1997) suggested that under extreme conditions (no sorption) cesium could reach groundwater along with the mobile constituents (chromate, technetium-99, and nitrate). Bulk movement of a large volume leak (simulated leak of 500 m<sup>3</sup> from tank SX-109) through the geologic strata reached groundwater within about 7 years and continued to drain for tens of years (Ward et al. 1997). As previously discussed, however, once the waste is diluted in ambient groundwater, sorption and retardation of cesium-137 and strontium-90 should occur. Thus groundwater monitoring wells would have to be very near the point of entry to detect cesium-137 and strontium-90. In addition, technetium-99 should be separated from the less mobile constituents and would be observed in downgradient monitoring wells long before either cesium-137 or strontium-90. For example, assuming a  $K_d$  of 10 and a groundwater flow rate of 50 - 100 m/yr, the strontium and cesium migration rate would be only 1 - 2 m/yr, under Hanford Site conditions. Thus if breakthrough occurred soon after the tanks were filled in the late 1950's, the example case suggests after 40 years (1958 - 1998) strontium-90 and/or cesium-137 would be about 40 to

80 meters from the point where they entered groundwater. Three or four older wells within the tank farms and at least one RCRA

monitoring well are within this distance from hypothetical tank leak sources (Figure 1.2). Colloidal phases may be more mobile and could even be covariant with the mobile contaminants (nitrate, technetium-99, and chromate).

The observed patterns of technetium-99, cesium-137, and strontium-90 occurrences in WMA monitoring wells are discussed with the respect to the above considerations, as follows.

### **3.8.1 Technetium-99**

Time series data for gross beta and a recent (1995) concentration contour plot of technetium-99 in the vicinity of the WMA are shown in Figure 3.11 in relation to locations. The gross beta is used here to illustrate time response patterns because it was measured more consistently and over a longer period than was technetium-99. The earliest technetium-99 measurements were made in 1986. Technetium-99 is typically about 2 to 3 times greater in magnitude than the gross beta in wells in the vicinity of the WMA (The low energy beta emissions from technetium-99 are less efficiently detected than the strontium-yttrium-90 beta source used for calibration). The corresponding technetium-99 concentration for the maximum gross beta in well 2-W23-1 was 8,250 pCi/L on 6/27/86 versus a gross beta concentration of 3,470 pCi/L. Since this same relationship holds in other samples from wells with transient technetium-99 occurrences (e.g., see data for well 2-W22-46, Appendix B), it seems safe to assume the earlier gross beta results used in Figure 3.11 can be attributed to primarily technetium-99. For example, if significant amounts of other mobile beta emitters such as ruthenium-106 had been present in the 1986 sample for well 2-W23-1, the technetium-99 to gross beta ratio would have been much smaller than 2 to 3.

It should also be noted that most of the data plotted for the wells shown inside the WMA (wells 2-W23-1, -2, -7, -3) are for samples collected with a bailer (no well purging prior to sample collection). There may be some lag effect between changes in ambient groundwater concentrations and the water inside the well bore in these cases. However, the fact that the concentrations change fairly rapidly over a 1-2 year period in these wells suggests the wells were in communication with the aquifer. The RCRA-compliant wells (i.e., 2-W23-15 and 2-W22-46 which are equipped with submersible pumps and purged prior to sampling) exhibit transient technetium-99 concentrations that are similar to those observed in the older bailed wells. Nevertheless, efforts are underway to have permanent pumps installed in the old wells inside the S and SX tank farms.

With the sampling conditions noted above in mind (e.g., a possible lag effect or broadening in the time-concentration plots for the bailed wells), Figure 3.11 indicates short-term transients occurred in the mid-1980s in the S farm and at later dates farther to the south-southeast and at the southwest corner of SX tank farm. While variable in magnitude, the transients seem to occur over a 1-2 yr time period, but at different times from 1985 to the present. It is also noteworthy that technetium-99 is trending upward once again in well 2-W23-1 located in the S tank farm (the most recent results for duplicates collected in August, 1997 were 1,200 and 1,500 pCi/L (Appendix B) compared to 180 pCi/L in 1996 and the 1986 maximum of about 8,200 pCi/L).

The observed time response patterns (Figure 3.11) suggest a similar transport mechanism is involved for the transient occurrences, but at different times and, at least in one case (well 2-W23-1), is apparently recurrent.

Figure 3.11. Technetium-99 Plume (1995) and Gross Beta Time Series Plots in Selected Wells

times

Near WMA S-SX (Technetium-99 concentrations are approximately two to three the gross beta concentrations in these wells.)

### 3.8.2 Cesium-137 and Strontium-90

Cesium-137 was detected in only one well (2-W23-7) which is at a location that is not immediately adjacent to any major or known tank leak or spill (underground waste transfer line leaks, however, cannot be ruled out as potential adjacent source). Low level counting methods were used to quantify the low concentrations (~10 to 14 pCi/L) that were associated with a particulate phase (based on the difference between filtered and unfiltered samples [Table 3.2]).

Spectral gamma logging of well 2-W23-7 indicated a formation cesium-137 concentration of 1 pCi/g or less both above and within the perforated (saturated) interval of the well (John Brodeur, personal communication, 1997). The equivalent cesium-137 per gram of solids filtered from the water sample was approximately 100 pCi/g. This isolated occurrence of cesium-137 observed in groundwater may be because of contamination of the well during maintenance or sampling activities (i.e., during sealing attempts, fugitive tank farm particulates, inflow of surface contamination during snowmelt runoff into the well at the surface). The particle-bound cesium in the bottom of the well, or on the interior surfaces of the casing, probably was resuspended by the temporary installation of the bladder pump used to obtain the samples for cesium-137.

Table 3.2  
Cesium-137 Results of Unfiltered and Filtered Samples Obtained From 2-W23-7

Sample Date	Results (pCi/L) $\pm 2\sigma$ counting error	
	Unfiltered	Filtered (0.4 $\mu$ m)
06/19/96	10.4 $\pm$ 3.4	1.0 $\pm$ 1.1
06/25/96	13.8 $\pm$ 2.8	2.0 $\pm$ 1.7

Strontium-90 was also detected in only one well, 2-W23-7, the same well where cesium-137 was detected. A concentration of  $6.2 \pm 1.6$  pCi/L (unfiltered) was reported for March 1996. This sample was collected with a bailer (i.e., no purging prior to sample collection). A temporary sample pump was installed in June 1996 and two sets of filtered and unfiltered samples collected as described for the cesium-137 (Table 3.2 and see Appendix B). In the latter case, unfiltered and filtered results for strontium-90 (6/25/96 sample) were  $1.7 \pm 0.9$  pCi/L and  $0.9 \pm 0.5$  pCi/L, respectively. The apparent decline in strontium-90 between 3/96 and 6/96 may in part be due to the well purging conducted. Nevertheless, the lower concentrations obtained for 6/25/96 are above the detection limit based on periodic measurement of blanks (Appendix B, Table B.3), and about two times the 2 sigma counting error associated with the individual determinations. Thus the analytical results are judged to be positive detections. Although this occurrence may be associated with internal well contamination, as discussed for cesium-137, the positive detection in the filtered sample result suggests there may be some strontium-90 in solution (fraction passing through a 0.4  $\mu$ m membrane filter).

Well 2-W23-7 is about 125 m downgradient from tank S-104, the location in the S tank farm with the greatest subsurface contamination (based on spectral gamma logging, DOE 1998). Other sources of contamination between the S and SX tank farm (e.g., transfer lines) would be potentially closer to the well.

Whether this represents breakthrough from the vadose zone and transport in the aquifer to well 2-W23-7, or is related to well construction (old well that was originally unsealed), cannot be determined at this time. Additional investigation of this occurrence is needed to resolve this uncertainty.

Except for the one well discussed above, the general absence of cesium-137 and strontium-90 in groundwater observed to date (Appendix B), and their absence where high technetium-99 concentrations have recently occurred (i.e., well 2-W22-46, see Table 3.1), implies these two tank waste components are much less mobile than technetium-99 in groundwater beneath WMA S-SX. Also, if there were a significant colloidal phase that travels with the technetium-99, the unfiltered sample results (Table 3.1 and Appendix B) for the well with maximum technetium-99 (2-W22-46) should have accounted for this hypothetical phase. Of course, this does not rule out colloids that move more slowly than technetium-99. Given the wide range in timing of technetium-99 transients, however, colloidal cesium-137, if present, should have been detected in unfiltered samples in at least some of the wells (e.g., in well 2-W23-1 where technetium-99 recently reappeared [see Appendix B] 11 years after the first observed transient peaked in 1986).



## 4.0 Discussion

Presumptive evidence presented in Section 3.0 indicates a source or sources of groundwater contamination exists (or existed) within WMA S-SX. If so, possible source locations should be consistent with temporal and spatial distributions of groundwater data, and a plausible driving force is needed to account for the movement of contaminants through the vadose zone to groundwater. Three possible scenarios are discussed in this section.

### 4.1 Temporal and Spatial Considerations

As part of groundwater quality assessment investigations conducted during Phase I, an attempt to correlate possible source locations to observed groundwater data and known dynamics is made. For this purpose, three scenarios are considered:

1. a single (northern) source to account for all groundwater occurrences of technetium-99 and mobile co-contaminants
2. a combination of (1) plus a source at the far southern end of the SX farm
3. addition of a third source to (2), consisting of the area identified with the greatest depth distribution of cesium-137 in the S-SX tank farms (in the vicinity of tanks 108, 109, 111).

#### 4.1.1 Scenario 1 (Single Source)

Previous contours of contaminant ratios and concentrations suggested that a source in the S tank farm area that was carried south through the WMA might account for the observation that technetium-99 seemed to “peak” here first and then later in wells to the south. While this would require a flow direction contrary to the inferred direction, preferential (lateral) flow through the aquifer is possible. The primary problem with this pathway is the timing of the peak technetium-99 occurrence in well 2-W23-15 on the southwest corner of the SX farm in 1993 and then the very recent occurrences in well 2-W22-46. These two dates make it impossible for a single path flowing north to south to intersect all the wells sequentially. In other words, a temporal discontinuity exists in a path that must pass all the wells in which technetium-99 has occurred.

#### 4.1.2 Scenario 2 (Two Sources)

In this scenario, two sources are postulated, one at the far south end of the SX farm (from the vicinity of tanks SX-114 and SX-115, [WHC 1992c]) and the same northerly source area considered in scenario 1. For the latter, the plume path deviates from a southerly flow to a southeasterly direction to accommodate the occurrences of technetium-99. These hypothetical plume paths and source areas are illustrated in Figure 4.1. Also plotted are the approximate dates of technetium-99 (and/or gross beta) maxima. Arrival times of technetium-99 (or gross beta) maxima, assuming a single source in S farm, between

wells 2-W23-1, 2-W23-7 and 2-W23-2 seem reasonable based on estimated flow rates for this area (approximately

**Figure 4.1.** Spatial and Temporal Correlation of Observed Technetium-99 in Groundwater and  
Possible Contaminant Source Areas in WMA S-SX (1986-1997)

25 - 50 m/yr). The last well in the hypothetical flow path, 2-W22-39, however, is inconsistent with a flow rate of 25 - 50 m/yr, if all four monitoring wells must intercept the same source.

With a hypothetical plume path originating in the southwest corner of the WMA the observed technetium-99 occurrences in wells 2-W23-15, 2-W23-6 and 2-W22-46 are both spatially and temporally consistent. For example, the distance between wells 2-W23-15 and 2-W22-46 is about 125 m. The indicated travel time of the technetium-99 peak between the two wells is approximately 5 years or 25 m/yr (assuming the sharp upward trend in 2-W22-46 will peak in 1998). This estimated flow rate is consistent with the very low hydraulic conductivity in this area (see Figure 3.8).

#### **4.1.3 Scenario 3 (Three Sources)**

This scenario is based on the assumption that the location of greatest depth of elevated vadose zone cesium-137 in the S-SX farms (DOE 1997; WHC 1992a,b) is indicative of a groundwater source of technetium-99. This scenario is illustrated in Figure 4.2 along with the SX-114-115 hypothetical source.

Based on the inferred southeasterly groundwater flow direction, a source originating in the vicinity of tanks SX-108-109-111 should be intercepted by well 2-W23-3. It seems inconceivable that a flow path from the subject source could bypass well 2-W23-3 and still reach wells 2-W23-6 and 2-W22-46 or 2-W22-39, except for the following possibility.

The observed occurrences can be explained if the plume path originating from the vicinity of SX-109 has shifted slightly more to the north so that it misses wells 2-W23, 2-W23-6, and 2-W22-46 (shown as path 2 in Figure 4.2). This could happen if groundwater flow direction shifted from southeasterly to easterly as suggested by the three-point solutions described previously. The lower or southerly plume path (path 1 in Figure 4.2) could account for the occurrences in 2-W23-15, 2-W23-6, and 2-W22-46 as previously described for Figure 4.1.

Thus, it may be necessary to invoke three separate source areas to accommodate the observed complex spatial and temporal distributions of technetium-99 for the WMA S-SX. If the three separate source areas are responsible for observed groundwater contamination patterns in the S-SX area, multiple driving forces at different times are needed to explain the concentration history of technetium-99 and co-contaminants in vicinity groundwater, as discussed in the following section.

## **4.2 Driving Force Considerations**

Potential driving forces for carrying contaminants to groundwater include 1) waste volume and tank-related factors (leak volume, fluid density, and enhanced infiltration/roof runoff), or 2) ponding and infiltration of surface runoff from utility line ruptures or leaking water lines and 3) natural infiltration events.

**Figure 4.2.** Hypothetical Groundwater Plumes Beneath Major Known Vadose Contamination

Zones in the SX Tank Farm

#### **4.2.1 Waste Volume and Tank Related Factors**

As previously discussed, the large volume, high density waste liquor scenario used by Ward, Gee, and White (1997) to model the SX-109 tank leak predicted the flux of mobile contaminants to groundwater should continue over a very long period. This implies that a slow but continuous downward trend in contaminant concentration versus time should be observed in downgradient wells from such sources. The driving force in this case is the enhanced infiltration (10 cm/yr annual average) because of: 1) the devegetated and graveled tank farm surface and runoff from the domed roof of the tanks; 2) the high tank liquor fluid density; and 3) the volume of the leak.

There is evidence at other 200 West waste disposal sites that long-term drainage of large volume, high density fluids does occur under Hanford (200 West Area) conditions. Piepho (1996) modeled the behavior of an aqueous and organic phase of carbon tetrachloride at the 216-Z-9 trench located just to the north of WMA S-SX. His model predictions showed long-term drainage from the crib source (tens of years following closure) to groundwater. This prediction agreed with groundwater monitoring results indicating there is a continuing input of carbon tetrachloride to groundwater beneath the 216-Z-9 trench. Also, at the northwest corner of the T tank farm, high specific conductance (because of sodium nitrate) persists suggesting there is a continuing input in that location. The source of this anomaly is attributed to the 216-T-7 crib and tile field, which received approximately 110 million liters of T tank farm supernate until 1955. Thus, long-term drainage could be occurring at these 200 West locations. The volumes of these sources, however, are sufficiently large to have exceeded multiple pore volumes of the sediment column beneath the disposal sites. In contrast, even the largest tank leak is near (or less) than one (vadose sediment) pore volume.

The elevated specific conductance in the 200 West Area shows the influence of tank-related waste (supernatant discharges and or leaks from tanks and ancillary systems) on vicinity groundwater. As noted above, the persistent high specific-conductance zone (because of sodium nitrate) along the northwest side of the T tank farm is attributed to the large volume of high salt waste discharged from T tank farm that apparently continues to drain to groundwater (see Figure 4.3). Thus, crib sources and tank leaks are difficult to distinguish from each other in the vicinity of the T tank farm.

#### **4.2.2 Utility Line Ruptures and Leaks**

Leakage from aging utility water lines is a widespread industry problem. The S-SX tank farms are surrounded by steam lines, raw water and potable water lines, many of which have been in the ground for over 50 years. Fire protection water lines are in close proximity to the contaminant zone in the southwest corner of the SX farm (see Figure 4.2). In addition, before about 1985 pressurized lines existed inside the tank farm for each self-boiling single-shell tank condenser. Since 1985, only pressurized feeder lines for fire hydrants entered the S and SX tank farm from a main distribution line located around the perimeter of the S-SX fenceline. The fire protection water is maintained at about 120 psi. When pressures drop, the common practice is to increase the flow of water to maintain the water pressure at 120 psi.

Thus, while only circumstantial evidence exists, water sources from pressurized lines existed near potentially significant sources of vadose zone contamination in the S and SX tank farms. Because the

condenser lines were isolated prior to 1985, washout of soil column contamination by infiltrating water from a condenser water line leak could account for the 1985-1986 technetium-99/gross beta transient in

**Figure 4.3.** Specific Conductance Contours. Inset highlights anomalies that occurred in 1997 using a 25  $\mu\text{S}/\text{cm}$  interval. The 410  $\mu\text{S}/\text{cm}$  value in S farm is associated with the reappearance of technetium-99 in well 2-W23-1. The 160  $\mu\text{S}/\text{cm}$  value (well 2-W23-7) suggests a raw water



source of local origin.

Specific conductance as an indicator of utility line water.

As can be seen from Figure 4.3, the well 2-W23-1. Because these lines were isolated permanently prior to 1985, this potential driving force has been eliminated. The fire protection water lines inside the farms theoretically were valved out as part of a program to eliminate all water sources to the tank farms (ca. 1990-1994). However, the line passing along the south fenceline of SX farm apparently was repressurized for other reasons (e.g., it was found to be unexpectedly pressurized when checked in the fall of 1996 in connection with the S-SX Phase I assessment (Doug Rohl, personal communication; there was no record of when the main supply line actually was reopened). Thus, development of a possible water leak overlying subsurface contamination from spills or tank leaks in the southwest corner of SX tank farm hypothetically could have occurred and caused the technetium-99 transient (and related co-contaminants) in well 2-W23-15.

Circumstantial or presumptive evidence of a water source or leak at this critical location (near monitoring well 2-W23-15) also is suggested by the growth of a small cottonwood tree approximately 8 ft (2.4 m) in height (Figure 4.4). Cottonwood trees require a reliable source of water to flourish. The appearance of such growth along water line runs is commonly used at Hanford to check for significant leaks (Doug Rohl, personal communication).

specific conductance in the vicinity of the S and SX tank farms is much lower than natural groundwater for the Hanford Site (approximately 340  $\mu\text{S}/\text{cm}$ ). This general pattern is attributed to the large volumes of relatively clean water discharged to U Pond and adjacent upgradient ditches and cribs. The raw water from the Columbia River used as makeup water is about 140  $\mu\text{S}/\text{cm}$ . In sharp contrast to the T farm area, the very low groundwater specific conductance in the vicinity of S and SX tank farms indicates the absence of a large input of high salt waste, consistent with past-practice waste disposal at the S and SX farms (i.e., only tank condensate was discharged to adjacent cribs from the S and SX farms).

Against this general background of low specific conductance, a “finger” of low ( $<250 \mu\text{S}/\text{cm}$  for 1996 and  $<200 \mu\text{S}/\text{cm}$  for 1997, Figure 4.3) specific conductance occurs across the SX tank farm. Specific conductance for well 2-W23-7 on the east side of the WMA was 160  $\mu\text{S}/\text{cm}$  in August 1997. As noted above, the supply water at Hanford is close to this value (i.e., Columbia River water at about 140  $\mu\text{S}/\text{cm}$ ). The low values noted may be the result of infiltration of water from the line rupture/flooding event that occurred in September 1996, or could be due to a subsurface leak in a utility line in this area. Whichever the case, it indicates a source of utility line surface water has passed through the vadose zone in the vicinity of the WMA. This could explain the recurrence of technetium-99 in well 2-W23-1, located just north of 2-W23-7. As previously noted, well 2-W23-1 is located near the largest known source of subsurface contamination in the S tank farm near tank S-104 (Figure 3.9) and near where ponding of the water from the line rupture in 1996 occurred.

The specific conductance considerations discussed above, and the observed short-term technetium-99 transients (see Figure 3.11) in groundwater in the vicinity of the S and SX tank farms, are not indicative of long-term drainage of a high salt source. The observations are more consistent with a near-surface leak or rupture event that washes contaminants out of the soil column relatively quickly or a random or short-term natural infiltration event, discussed as follows.

**Figure 4.4.** Cottonwood Tree Near Southwest Corner of SX Tank Farm (Photo taken in July 1997; approximate height of tree is 2.5 m. The bank immediately behind the tree is chained and marked as a surface or near-surface contamination zone. The tank farm fence and surface structures can be seen in the background near the top of the photo.)

Either a short-term infiltration (flooding) event, or a small continuous water line leak, perhaps coupled with short circuit pathways to groundwater, could account for the observed technetium-99 and gross beta transients shown in Figure 3.11. Even continuous small leak rates ( $<1$  L/min) can hypothetically reach groundwater and thus are capable of transporting contaminants from the upper soil column (Collard, Davis, and Barnett 1996).

### **4.2.3 Short-Term Random Natural Events**

Natural precipitation events have been noted in the past that could supply surface water for a “pulse” of water that conceivably could migrate through a contaminant zone and thus supply contaminants to groundwater over a relatively short period. The most likely meteoric event to supply surface water runoff and ponding at the surface is rapidly melting snow after accumulation of a significant snow pack. Snow pack and melting information have been recorded at the Hanford weather station since 1981. The total inches of snow that melted rapidly for each month since 1981 are shown in Figure 4.5. Typically, these totals comprise more than one event in years when rapid snowmelts occurred. Figure 4.5 provides an indication of possible events that may correlate with some groundwater observations.

The years 1983-1986, 1993, and 1996-1997 stand out in Figure 4.5. It has been previously noted that 1993 was a year with the largest snow pack on record. The year 1996-1997 was both wet and high in snow melt runoff. These time periods at first seemed to coincide with the appearances of technetium-99 peaks in groundwater just south of the WMA. However, the delay time between when the melting event occurs and contaminants arrive at the nearest well must be considered qualitatively. With this in mind, the times of peak technetium-99 arrival summarized in Figure 4.1, and considering the spatial and source location constraints previously discussed, only the occurrence at well 2-W23-1 seems to correlate with a snowmelt event. This well is an older well (poor or uncertain seal) and is located next to a single-shell tank that is not known to be a leaker. Tank S-104, however, is a known or suspected leaker and is located approximately 50 m north. Possible source-well-distance-travel time and snowmelt events seem consistent for this occurrence. However, if this type of event does occur it seems as though similar melting events would have occurred before 1981 and would have depleted the technetium source long ago.

Similar considerations at 2-W23-15 suggest that a snowmelt event could not account for the 1993 peak because the increase in technetium-99 actually began to rise in 1992. Thus, even if the subject well were located directly within the zone of infiltration and the contaminant zone, the timing is off by a year to be correlated with a snowmelt event. In addition, as noted above, if a major snowmelt/soil column washout is a driving force near the subject wells, this should have occurred in earlier years (prior to snowmelt records) and there would presumably be little if any residual soil column contamination in that area for subsequent events. This assumes that the soil column contamination is not replaced (i.e., as in a slow tank leak).

The above considerations point more strongly to artificial sources of water from either ruptures or intermittent utility line leaks. Nevertheless, diverting or minimizing surface water runoff is an important consideration as a general practice in controlling non-point source pollution.

**Figure 4.5.** Frequency Plot of Rapid Snowmelt Events, 1981-1997 (Cumulative total snowmelt for each month comprises only snow that melted more than 0.5 in., or 1.3 cm, within 24 hours; months for which no data are shown are months when no recorded rapid snowmelt events were recorded.)

## 5.0 Conclusions

Based on additional groundwater measurements and related data acquired during the Phase I assessment, coupled with interpretation of new and previous findings, we arrive at the following conclusions:

- Distribution patterns for radionuclides and RCRA/dangerous waste constituents (nitrate and chromate) in the vicinity of WMA S-SX indicate this WMA has contributed to groundwater contamination observed in downgradient monitoring wells.
- Multiple sources (tank leaks or spills) in the WMA are needed to explain historical as well as recent groundwater contamination (see Figures 4.1 and 4.2). At least two WMA source areas are needed to explain the technetium-99 transients observed for 1985-1987 in well 2-W23-1 and the more recent events observed in wells 2-W23-15 and 2-W22-46.
- The drinking water standard for technetium-99 has been exceeded but is currently limited to two wells at the southeast corner of the SX tank farm (2-W22-46 and 2-W23-6) and one well (2-W23-1) located along the east side of the S tank farm. Technetium-99, the constituent with highest concentration relative to a standard, is currently 4 to 5 times the EPA interim drinking water standard of 900 pCi/L in well 2-W22-46. The drinking water standard for nitrate has been exceeded and is currently limited to one well, 2-W22-46, with concentrations at/or slightly above the 45,000 µg/L standard.
- Technetium-99, nitrate, and chromium concentrations in downgradient well 299-W22-46 (the well with the highest current concentrations) appear to be declining after reaching maximum concentrations in May 1997. Observations during the next four quarters are needed to confirm the apparent declining trend in this well.
- Circumstantial evidence suggests short-term contaminant transients in multiple wells that occurred at different times between 1985 and present may have been caused by leaking water lines, rupture events and/or ponded snow melt water adjacent to and within the WMA. Continuing efforts are underway to identify and eliminate potential water sources within or around the tank farms.
- Cesium-137 and strontium-90 were not detected in any of the RCRA-compliant monitoring wells. This observation supports the expected retention or retardation of these radionuclides in Hanford soils and/or aquifer sediments.
- Low but detectable strontium-90 and cesium-137 were found in one old well (2-W23-7) located inside and between the S and SX tank farms. Whether this occurrence represents breakthrough from a vadose zone source to groundwater, or is a result of faulty well construction cannot be determined at this time. Additional investigation is necessary to determine if the low level contamination is borehole related or is more broadly distributed in the aquifer.

- Preliminary results for groundwater samples collected on 1/13/98 from a new borehole (41-09-39), drilled through the primary contaminant zone down to groundwater in the SX tank farm, suggest little if any tank waste reached the water table at this location. Gross alpha and gross beta concentrations,  $2.3 \pm 0.7$  and  $16.6 \pm 4.0$  pCi/L (based on 10 sample results), respectively, are within the range of Hanford Site natural background, and hexavalent chromium, a RCRA dangerous waste constituent and indicator of mobile constituents in tank waste, was not detected ( $<10$  µg/L).
- A Phase II investigation is needed to determine the nature, extent, and source(s) of recurrent groundwater contamination attributable to WMA S-SX.

## 6.0 Proposed Phase II Investigation

The objectives of the proposed Phase II investigation are: 1) to resolve uncertainties identified during the Phase I investigation; 2) to assess the fitness-for-use of older non-RCRA compliant wells within the WMA; 3) to further delineate the nature and extent of contamination to support possible corrective action options and 4) to determine if/when the site can be returned to detection monitoring status.

Specific decisions to be made in the Phase II investigation include the following:

- Whether concentrations of nitrate, chromium, and technetium-99 continue to decline in 2-W22-46;
- Whether the upward trend of technetium developing in 2-W23-1 reverses its course and declines; and
- Whether the apparent positive occurrences of cesium-137 and strontium-90 in well 2-W23-7 prove to be a borehole related effect.

If contaminant concentrations continue to decline in 2-W22-46 and a declining trend is observed in 2-W23-1, and the positive occurrences of cesium-137 and strontium-90 in well 2-W23-7 prove to be a borehole related effect, the groundwater program at this regulated unit will be recommended for return to detection monitoring status with site-specific indicators. In either case, upgrades to the network will be needed. For example, as water level continues to decline and flow direction shifts in the 200 West Area, replacement wells will be needed to maintain adequate spatial coverage and to optimize the leak detection capability of the WMA's groundwater monitoring well network.

Specific components or tasks include the following:

- Continue quarterly monitoring of constituents of interest in the existing S-SX network and extend well coverage, especially for the S tank farm using existing older wells to the fullest extent possible.
- Increase sampling frequency in well 2-W23-1 to quarterly or monthly, if necessary, to assess the upward trend in technetium-99 currently developing in this well.
- Addition of older upgradient wells (e.g., 2-W23-9) to the network to account for elevated nitrate that appears to be approaching WMA S-SX from the west-northwest.
- Test the representativeness of samples from the old monitoring wells inside the tank farms that have exhibited detectable strontium-90 and cesium-137 (2-W23-7) and technetium-99 (2-W23-1). Large volume purging (>4,000 liters) with periodic sampling is proposed for this purpose. If concentrations remain consistent over the extended purging cycle, aquifer contamination is indicated. If the concentrations decline rapidly with volume removed from the well, a borehole related effect is indicated. If the latter condition is observed, the well will be judged unsuitable for sampling and will be recommended for decommissioning to ensure downward movement around the outside of the casing is prevented.



- Investigate selected or targeted areas for indications of moisture and water sources that could account for periodic occurrences of groundwater contamination observed in monitoring wells. For this purpose, geophysical methods to assess the presence or absence of abnormal moisture content in the southwest corner of the SX tank farm and the northeast area of S farm could be used. Evaluation of local topography to assess runoff and water accumulation potential would also be a useful adjunct to the geophysical moisture survey.

## **6.1 Approach -- A Path Forward**

A Phase II assessment plan will be proposed and implemented in FY98, after regulator and other stakeholder comments on the Phase I report are addressed. Monitoring will continue on a quarterly schedule, supplemented by monthly as needed, during the interim while the Phase II plan is prepared and undergoes review by stakeholders. Once comments have been resolved, field activities will be coordinated with the TWRS vadose characterization activities and the sitewide integrated vadose/groundwater program.

## 7.0 References

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